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The Effect of High-Tensile Electric Fence Designs on Big-Game and Livestock Movements

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Abstract

*We used infrared-activated video cameras and direct observation to evaluate the effects of 2-wire high-tensile electric fence (2-WF), 3-wire high-tensile electric fence (3-WF), and 4-wire high-tensile electric fence (4-WF) designs on elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), and pronghorn (*Antilocapra americana*) movements. In addition, high-tensile electric fences (HTEF) were tested for their effectiveness on domestic cattle (*Bos taurus*; 2-WF and 3-WF) and bison (*Bison bison*; 3-WF and 4-WF). Shock energy on the test fences ranged from 0.5–4.5 J. The wildlife species we studied were physically capable of crossing all of the fence designs. However, difficulty in crossing the fences varied between species and designs. The elk and mule deer observed were more successful (100%) at crossing the 2-WF than pronghorn (51%). Mule deer (95%) and pronghorn (91%) were more successful at crossing 4-WF than elk (59%). The majority of elk (79%), mule deer (93%), and pronghorn (97%) successfully crossed 3-WF. Electric shock did not appear to affect elk, mule deer, or pronghorn at a charge of 0.5–4.5 J, and overall <1% were shocked when interacting with HTEF. For domestic cattle, 2-WF was 99% effective in calf separation tests and 100% effective for bull separation. Bison were successfully contained by both 3-WF (100%) and 4-WF (99.8% [~100%]). Our data suggest the 3-WF design overall was the least restrictive for elk, mule deer, and pronghorn and effectively confined domestic cattle and bison.*
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Key words

Antilocapra americana, *big game, bison,* Bison bison, *cattle,* Cervus elaphus, *electric fence, elk, fences, mule deer,* Odocoileus hemionus, *pronghorn*.

Fences can impact movements of mule deer (*Odocoileus hemionus*; Falk et al. 1978, Ward et al. 1980), elk (*Cervus elaphus*; Adams 1982), and especially pronghorn (*Antilocapra americana*; Spillett et al. 1967, Oakley 1973, Yoakum et al. 1980). Many fence design recommendations have been developed specifically to reduce impacts to big-game species (Autenrieth 1978, Yoakum et al. 1980, Kindschy et al. 1982, U.S. Department of the Interior et al. 1988, Wyoming Game and Fish Department 2005). However, many of the fences constructed in Wyoming do not follow those design recommendations (Riddle and Oakley 1973, De Groot 1992). For example, highway right-of-way fences, according to Wyoming Department of Transportation policy, must be a minimum of 114 cm tall and comprised of at least 4 wires. Private-land fences are not restricted to a maximum height or number of wires (Wyoming Statute § 11–28–102).

Since the early 1980s, high-tensile electric fence (HTEF) has become increasingly popular in Wyoming (M. Renner, Meeteetse, Wyo., USA, High Country Power Fence, personal communication). The HTEF differs from other types of electric fence because it is constructed with wire that has a greater tensile strength, generally between 170,000 and 200,000 pounds per square inch (McCutchan 1980). Private and public land managers are using a variety of HTEF designs to accomplish different results such as enclosing bison (*Bison bison*) or discouraging overuse of riparian habitats by cattle (*Bos taurus*; M. Renner, High Country Power Fence, Meeteetse, Wyo., USA, personal communication). The United States Department of the Interior (USDI) Bureau of Land Management (BLM) in Wyoming constructs electric fencing to exclude feral horses from sensitive locations and as a grazing management tool on rangeland (U.S. Department of the Interior, Bureau of Land Management 2000). The Wyoming Game and Fish Department (WGFD) uses HTEF to exclude cattle from vegetation treatment areas (Gary Butler, WGFD, Cheyenne, Wyo., USA, personal communication). With the increased popularity of HTEFs, there was a need to identify designs that allow necessary wildlife movements while effectively enclosing livestock. Our objective was to determine if elk, mule deer, pronghorn, bison, and cattle penetrate the 3 most common HTEF designs in Wyoming.

Study Area

We collected data from 8 private ranches in Wyoming (Antler Ranch, Elk Mountain Ranch, Renner Ranch, Three-Quarter Circle Ranch, Medicine Creek Ranch, Warren Ranch, Sunflower Ranch, and White Ranch), a WGFD research facility in southeastern Wyoming (Sybille Wildlife Research and Education Unit), a private ranch in Colorado (Diamond Tail Ranch), 1 BLM fence located near Farson, Wyoming, and a highway right-of-way fence near Laramie, Wyoming (Fig. 1) between the spring of 2000 and early winter of 2003. Major types of vegetation represented at these sites ranged from high-elevation grassland to sagebrush steppe and montane forest (Knight 1994). All but 3 of our research fences used for monitoring wildlife reactions had been in existence for 3 or more years. The exceptions were the Farson BLM fence constructed in conjunction with this research, the newly constructed private fence on the Three-Quarter Circle Ranch, and the state highway right-of-way fence that we constructed. All fences monitored for cattle responses (White Ranch, Warren Ranch, Medicine Creek Ranch) and 2 fences monitored for bison response (Sybille Wildlife Research and Education Unit and Sunflower Ranch) were newly constructed. We collected all other bison data on pre-existing fences.

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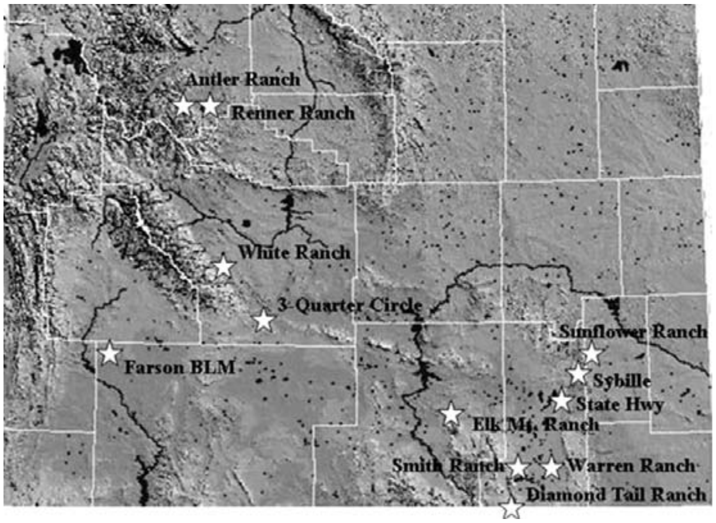

Figure 1. Study area locations in Wyoming and Colorado. Elk, deer, pronghorn, cattle, and bison data were collected from 8 private ranches in Wyoming and 1 in Colorado and from 3 state or federal government properties between spring 2000 and early winter 2003.

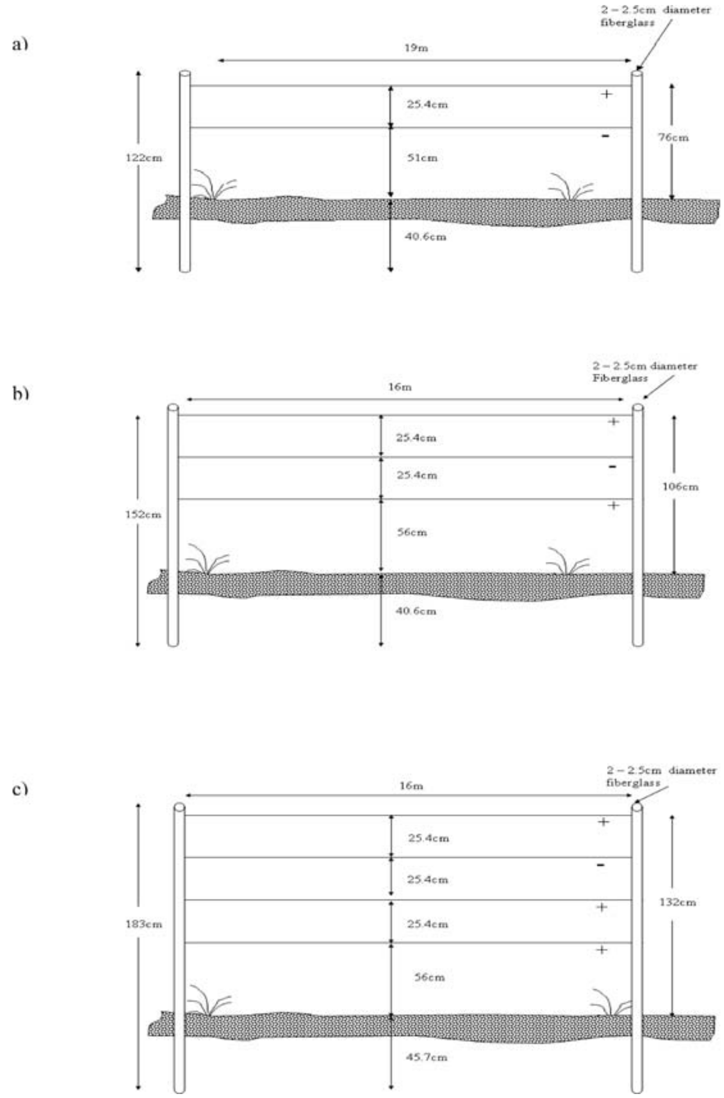

Figure 2. High-tensile electric fence designs used in this study between spring 2000 and winter 2003. Elk, deer, and pronghorn data were collected from all 3 designs. Cattle data were collected on 2- and 3-wire designs, while bison data were only collected on 3- and 4-wire designs. (a) Two-wire electric fence design. This fence is comprised of a ground wire 51 cm above the ground and an electrified wire 76 cm above the ground. Line posts are 2–2.5-cm-diameter × 122-cm-tall solid fiberglass spaced 19 m apart. (b) Three-wire electric fence design. This fence is comprised of electrified wires at 56 cm and 107 cm and a ground wire at 81 cm. Line posts are 2–2.5-cm-diameter × 152-cm-tall solid fiberglass spaced 16 m apart. (c) Four-wire electric fence design. This fence is comprised of electrified wires at 56, 81, and 132 cm and a ground wire at 107 cm. Line posts are 2–2.5-cm-diameter × 183-cm-tall solid fiberglass spaced 16 m apart.

Methods

We tested 3 different HTEF designs. Two-wire fence (2-WF) was comprised of a ground wire 51 cm above the ground and an electrified wire 76 cm above the ground. Line posts were 2–2.5-cm-diameter × 122-cm-tall solid fiberglass spaced 19 m apart (Fig. 2a). Three-wire electric fence (3-WF) was comprised of electrified wires at 56 cm and 107 cm and a ground wire at 81 cm. Line posts were 2–2.5-cm-diameter × 152-cm-tall solid fiberglass spaced 16 m apart (Fig. 2b). Four-wire fence (4-WF) was comprised of electrified wires at 56, 81, and 132 cm and a ground wire at 107 cm. Line posts were 2–2.5-cm-diameter × 183-cm-tall solid fiberglass spaced 16 m apart (Fig. 2c). These fence designs are relatively common in Wyoming (U.S. Department of the Interior, Bureau of Land Management 2000).

Through conversations with ranchers and wildlife biologists, we learned that these designs were perceived as most likely to allow wildlife to cross but to still contain cattle and bison. The 2-WF and 3-WF designs are similar to design specifications for 3-WF cross-cattle-fence and 2-WF cross-cattle-fence (Gallagher™, San Antonio, Texas). The 4-WF, primarily used to contain bison, did not follow Gallagher design specifications, but most were made with Gallagher products.

We used 10 battery-powered video cameras (Sony®, New York, New York) in combination with 10 Trailmaster® 700v passive infrared game monitors (Goodson and Associates, Lenexa, Kansas) to record wildlife and cattle responses to electric fences. We strapped the monitor to either a wooden brace post within the fence line, a nearby tree, or a post that we placed near the fence for this purpose. We used the least sensitive settings to minimize false activations. We strapped the video camera, which was protected by a 15-cm-diameter polyvinyl chloride pipe housing, to the post or tree with black rubber bungee straps just above the infrared monitor. We checked cameras and replaced film and batteries approximately every 14 days. The Sony NP-F550 battery was adequate for powering the camera for at least 2 hr of recording time. When in constant use, batteries on the infrared monitors had to be replaced every 3 months.

Wildlife

We only considered elk, deer, or pronghorn recorded on videotape or observed directly as data points if they approached to within ≤5 m of the fence and were moving toward it. We recorded and analyzed the final outcome of the interaction with the fence as "cross" if an animal was able to get to the other side of the fence while on camera or "avert" if the animal approached the fence and

Cow elk jumping 2-wire electric fence.

was turned away 2 or more times. If an animal crossed after turning away 2 or more times, we still considered them an "avert."

Cattle and Bison

We collected cattle data on 2-WF and 3-WF. To create a situation in which cattle would be motivated to challenge a fence, we separated cow–calf pairs (White Ranch = 75, Warren Ranch = 50, Medicine Creek Ranch = 300) in the autumn and separated bulls (White Ranch = 6, Warren Ranch = 4, Medicine Creek Ranch = 22) from cow–calf pairs in late spring. Cow–calf pairs had a strong desire to reunite (having never been separated), and the bulls were motivated to cross the fence to breed with cows that were coming into their first estrus after calving in early spring. In all cases only the test fence separated the study groups. Cattle breeds included Black Angus–Limousin cross (White Ranch), Charolais (Warren Ranch), and Black Angus and Corriente (Medicine Creek Ranch).

In addition to bison data collected on pre-existing 4-WF and on 1 pre-existing 3-WF, we collected data on 2 newly constructed 3-WFs. Sixteen bison at the Sunflower Ranch were in a 40-ha pasture enclosed by a poorly constructed 5-wire HTEF that the animals were accustomed to traveling through. We built an L-shaped study fence that tied into the 5-wire electric fence on the other 2 sides. We corrected the problems with the 5-wire fence before releasing the bison into the newly created 0.6-ha enclosure.

There were only 3 bison (2 cows and 1 bull) available at Sybille Wildlife Research and Education Unit. However, the animals were habituated to each other, and the 10-year-old bull had never been separated from the cows. A 0.4-ha (1-acre) enclosure was constructed, and the 2 cows were placed in the enclosure. The 3-WF was the only barrier that separated the bull from the cows during the test period.

We collected data at each location for 7 days after the animals were first released into the test pastures and exposed to the new fences. If an animal stayed on the correct side of the fence during the monitoring period, we considered it a "contain." If the animal was sighted or video recorded on the other side of the fence, we counted it as an "escape." We noted ear tag numbers of escaped animals to avoid recounting the same animal. All cattle or bison within a pasture did not necessarily contact or receive a shock from a test fence while on camera or while under direct observation. For this study we assumed that all cattle and bison had an equal opportunity to contact the fence. Thus, we included all animals within the pasture as sample points for the data analysis.

Electric Pulse Meter (Joule Meter)

A voltmeter is an effective tool for determining if a fence is maintaining desired voltage (V) and for identifying short circuits. However, a V measurement alone is not adequate for measuring the shock energy, joules (J) available on a fence or for comparing shock energy between different fences (Hancock 1995). To determine J available at any point on a particular fence, we needed to know V, amps (A), pulse shape, and pulse length. We used a standard resistance of a mature cow, 500 ohms, for all J-meter readings because this was the only resistance setting available on the meter that was close to the body size of our test subjects. We measured the J output of every fence at each camera location each time we checked the cameras (approximately every 14 days).

Table 1. Chi-squared tests of high-tensile fence designs × outcomes for elk, mule deer, and pronghorn on selected ranches in Wyo. and Colo. (2000–2003).

Species	Design	*n*	*N*[a]	% shocked	Outcome[b]	
					% cross	% avert
					$\chi^2 = 44.5, P = <0.001$	
Elk	2-wire fence	17	2	11.8	100	0.0
Elk	3-wire fence	52	3	5.8	78.8	21.2
Elk	4-wire fence	369	6	1.4	58.5	41.5
					$\chi^2 = 0.7, P = 0.8$	
Mule deer	2-wire fence	8	2	0.0	100	0
Mule deer	3-wire fence	56	2	5.4	92.9	7.1
Mule deer	4-wire fence	19	2	0.0	94.7	5.3
					$\chi^2 = 246, P < 0.001$	
Pronghorn	2-wire fence	130	4	0.0	50.8	49.2
Pronghorn	3-wire fence	354	3	0.0	96.9	3.1
Pronghorn	4-wire fence	79	4	0.0	91.1	8.9

[a] *N* equals the number of data collection sites monitored that contributed to the total sample *n* and were considered significantly independent.

[b] Animals that approached a fence and were turned away more than once were considered an "avert." Animals that approached and successfully crossed after being turned away ≤1 time were recorded as "cross."

Table 2. Chi-squared tests of high-tensile fence designs × outcomes for domestic cattle and bison on selected ranches in Wyo. and Colo. (2000–2003).

Species	Design	n	N[a]	Outcome[b]	
				% Escape	% Contain
Bull–cow separation				χ^2 = not applicable	
Cattle	2-wire fence	32	3	0	100
Cattle	3-wire fence	32	3	0	100
Calf–cow separation				$\chi^2 = 11.1$, $P = 0.01$	
Cattle	2-wire fence	850	3	1.3	98.7
Cattle	3-wire fence	850	3	0	100
Herd containment				$\chi^2 = 0.01$, $P = 0.78$	
Bison	3-wire fence	44	3	0	100
Bison	4-wire fence	1,144	3	0.2	99.8

[a] N equals the number of data collection sites monitored that contributed to the total sample n and were considered significantly independent.
[b] Animals that were held by the fence during the testing period were recorded as "contain." Animals that escaped containment were recorded as "escape."

Data Analysis

We used a 3 × 2, design × outcome chi-square analysis to test wildlife data and the null hypothesis that the proportion of individuals of each species that successfully cross the fence (cross) or are turned away by the fence 2 or more times (avert) does not differ between electric fence designs.

To analyze bison data, we used a 2 × 2, design × outcome chi-square analysis to test the null hypothesis that the proportion of individuals that are held by the fence (contain) or not held (escape) does not differ between fence designs. For cattle, we used the same chi-square design to test the following 2 null hypotheses: 1) the proportion of weaned calves and cows that are held by the fence (contain) or not held (escape) does not differ between fence designs and 2) the proportion of bulls that are held by the fence (contain) or not held (escape) does not differ between fence designs. We considered results of chi-square tests significant at $P \leq 0.05$.

Care and handling protocols were reviewed and approved by the Wyoming Game and Fish Department Animal Care and Use Committee.

Results

Wildlife

We collected 1,084 wildlife responses to electric fences (Table 1). Only 1% ($n = 14$) of the 1,084 animals received a visible shock when interacting with the electric fences. Of those 14, 3 were shocked by fences charged with 0.5–1.5 J, 9 by fences charged with 1.6–3.4 J, and 2 by fences charged with 3.5–4.5 J. The J rating varied between different fences that were monitored for wildlife responses because energizers used to power the fences varied by location. The insulating quality of hollow ungulate guard hairs, combined with dry soils, appear to allow elk, mule deer, and pronghorn to contact an electrified wire in the 0.5–4.5-J range without receiving a shock. However, if an animal touched an electrified wire with their nose or ears or was standing on moist soil and forced the electrified wire closer to their skin by leaning into the fence, they would be more susceptible to being shocked (McCutchan 1980).

Elk.—We collected 438 elk interactions with HTEF. On 2-WF none of the elk were averted compared with 21% aversion on 3-WF and 42% aversion on 4-WF ($\chi^2 = 44.5$, $P \leq 0.001$). Two percent of elk ($n = 9$) were shocked by the electric fences.

Deer.—We collected 83 deer interactions with HTEF. On 2-WF, none of the deer were averted compared with 7% aversion on 3-WF and 5% aversion on 4-WF. Less than 4% of deer ($n = 3$) were shocked by HTEF ($\chi^2 = 0.7$, $P = 0.8$).

Pronghorn.—We collected 563 pronghorn interactions with HTEF. Pronghorn exhibited low aversion rates at 3-WF (3%) and 4-WF (9%) but displayed relatively high aversion rates (49%) on 2-WF ($\chi^2 = 246$, $P \leq 0.001$). Less than 1% of pronghorn ($n = 3$) were shocked by HTEF.

Cattle and Bison

Cattle.—We observed 1,764 cattle interactions with electric fence (Table 2). We observed no difference between fence design and outcome for bull separation tests; in fact, 100% of the bulls ($n = 32$) were contained by both 2-WF and 3-WF. There was a difference observed between fence design and outcome for the calf-separation test ($\chi^2 = 11.1$, $P = 0.01$). We observed 100% separation of calves and cows during weaning tests on the 3-WF and 99% separation on 2-WF. The HTEF designs effectively

Bull separation test.

separated calves from cows and bulls from cows. We contend that, functionally, there is no difference between 99 and 100%.

Bison.—We collected 1,188 bison reactions to electric fence (Table 2). Both 3-WF and 4-WF effectively contained bison ($\chi^2 = 0.01$, $P = 0.78$). We observed 100% containment on 3-WF ($n = 44$) and 99.8% containment on 4-WF ($n = 1{,}144$). The tested HTEF designs effectively contained bison.

Discussion

Elk aversion rates increased as the top-wire height increased. Both the 2-WF and 3-WF were relatively easy for elk to traverse, and the animals appeared less anxious when interacting with these fences. We observed a relatively high aversion rate on the 4-WF. When attempting to cross 4-WF, we observed 3 cow elk flip 180 degrees and land on their backs when tripped by the top wire. All of our video and direct observation data suggest that elk are more apprehensive about crossing 4-WF and that crossing 4-WF presents a greater risk of physical harm than the other fence designs. The majority of our 4-WFs were located in areas that received heavy elk migratory pressure. The herd would bunch against the fence as they anticipated the crossing, and individuals would run up and down the fence for 50–100 m in both directions before a lead cow would attempt the first crossing. After the first few crossed, the majority of the remaining animals would attempt to jump the fence. Many would approach and turn away from the fence 2 or more times (avert) before they would successfully cross. When these herds crossed, there were always 2 or 3 remaining stragglers that would run down the fence line and out of sight.

Mule deer tend to jump over fences when startled and crawl under the bottom wire when calm (Mackie 1981). Since we used infrared-activated video cameras to collect data, deer generally were calm when interacting with test fences, and the majority (57%) did crawl under the bottom wire to cross. Our data indicate mule deer exhibit low aversion rates on all fence designs, and there appears to be no advantage of one over another for allowing mule deer to cross.

Compared with 4-wire barbed fences (bottom wire heights ranging from 15–41 cm), a bottom wire height of 51 cm (2-WF) or 56 cm (3 and 4-WF) is relatively high and should provide plenty of space for pronghorn to traverse under the fence (Yoakum et al. 1980, Kindschy et al. 1982, Hall 1985). On 3-WF and 4-WF, all pronghorn that traversed the fence did so by ducking under the bottom wire. Similarly on 2-WF, 87% of pronghorn that successfully crossed the fence went under the bottom wire.

Aversion rates on 2-WF were relatively high (60%). We collected the majority of our 2-WF data at fences that were newly constructed in the spring of 2001. The fences were continually monitored from June 2001 through January 2003. Aversion rates did not decrease over the 20-month monitoring period. Often, where a fence has been in existence for a number or years, pronghorn will use the same site to cross under a fence in a slight depression that allows easier access (Kie et al. 1994). Although some adult pronghorn may become adept at jumping fences up to 80 cm high, the majority of pronghorn will go under a fence rather than jump or negotiate their way through (Wormer 1969, Oakley 1973, Kie et al. 1994). The 76-cm-top-wire height on 2-WF may be just at or above the level at which pronghorn are comfortable jumping. Instead of quickly crossing under the bottom wire as was the case on 3-WF and 4-WF, they may have hesitated longer on 2-WF because the fences were not only relatively new but were of a design (low top-wire height) that was not commonly encountered by pronghorn in our study area (L. Porter, BLM, Rock Springs, Wyo., USA, personal communication). Thus, psychological conflict and fear of novel objects may explain why a high rate of aversion was observed on the 2-WFs (Hebb 1946).

A good fence contains cattle and makes livestock production possible. It also promotes good relationships with neighbors, lessens accidents from animals escaping onto roads, and increases land values (Ensminger and Perry 1997). Both 2-WF and 3-WF were effective at keeping bulls separated from cows in the spring (100% on 2-WF and 3-WF) and calves separated from their mothers in the autumn (99% on 2-WF and 100% on 3-WF). If 2-WF and 3-WF are properly constructed and maintained, they provide an effective barrier to domestic cattle.

Lee (1990) suggested 5-wire HTEF with a total height of 102 cm provides excellent control of domesticated bison that have been trained to respect electric fence. In controlled tests with bison, 3-WF effectively contained yearling bison and bison bulls when separated from other members of the herd (C. J. Quitmeyer et al., Wyoming Cooperative Fish and Wildlife Research Unit, Laramie, Wyo., USA, unpublished report). Our data indicate both 3-WF (152-cm total height) and 4-WF (132-cm total height) effectively contain bison. The higher top wire on a 4-WF is not likely needed to contain bison if they are trained to respect electric fence and are well managed. A well-managed herd is kept content by providing them with adequate space, forage, and water. If these basic necessities are not provided, then these HTEF designs and other woven-wire and barbed-wire fence likely will fail (Jennings 1978, Lee 1990).

Management Implications

We examined the effects of 2-WF, 3-WF, and 4-WF on elk, mule deer, and pronghorn movements. All three species were physically capable of traversing all test fence designs. The difficulty in crossing the fences varied between species and design. With 2-WF, elk and deer easily crossed, but pronghorn had relatively high aversion rates. Three-wire fence was effective at containing cattle and bison and was the best design for allowing elk, mule deer, and pronghorn to traverse. Four-wire fences were relatively easy for mule deer and pronghorn to cross but were difficult for elk to cross.

Electric shock did not appear to be a factor affecting the reaction of elk, mule deer, or pronghorn to electric fences in the range of shock energy used (0.5–4.5 J). Less than 1% of these species (9 elk, 2 deer, and 3 pronghorn) were shocked when interacting with electric fence.

Of the designs examined in this study, a 3-WF may be the best design to meet the goals of both cattle and bison producers (to contain livestock) and wildlife managers (to allow wildlife passage) when all 3 wild ungulates are present in the area. Any of the tested fence designs may be appropriate if deer are the only big-game species in the area. If pronghorn are the primary species of concern, then either 3-WF or 4-WF may be appropriate. Both 2-

WF and 3-WF are appropriate in situations in which elk are the primary wildlife concern.

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Stanley Anderson (left) received his B.S. from the University of Redlands and his M.A. and Ph.D. from Oregon State University. Dr. Anderson was the leader of the Wyoming Cooperative Fish and Wildlife Research Unit and Professor in the Department of Zoology and Physiology at the University of Wyoming from 1980–2005. He passed away on September 1, 2005, at the age of 66. Dr. Anderson has an international reputation for his research in bird ecology and the preservation of rare and endangered vertebrates. In recent years his research focused on animals such as the greater sage-grouse, pygmy rabbit, burrowing owl, and black-footed ferret. During his tenure as leader of the Cooperative Unit, he published over 200 papers and books on wildlife biology subjects. Dr. Anderson was proud to have advised or coadvised 100 graduate students while serving at the University of Wyoming. His students now serve as faculty at other universities, biologists with state and federal natural resource management agencies, leaders within nongovernment conservation organizations, and a wide variety of other wildlife-oriented professions. Dr. Anderson was particularly fond of referring to his students as his "academic progeny."

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